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MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FLIGHT TESTS OF A 1/8-SCALE MODEL OF THE

BELL D-188A JET VTOL AIRPLANE

TED NO. AD 3147

SERVICE REPORT

By Charles C. Smith, Jr.

Langley Research Center
Langley Field, Va.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

The Bell D-188A VTOL airplane is a horizontal-attitude VTOL fighter with tilting engine nacelles at the tips of a low-aspect-ratio unswept wing and additional engines in the fuselage. The model could be flown smoothly in hovering and transition flight. In forward flight the model could be flown smoothly at the lower angles of attack but experienced an uncontrollable directional divergence at angles of attack above about 16°.

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Control, Directional	1.8.2.3
Flying Qualities	1.8.5

*Title, [redacted].

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TED NO. AD 3147

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SUMMARY

An experimental investigation has been made to determine the dynamic stability and control characteristics of a 1/8-scale flying model of the Bell D-188A jet vertical-take-off-and-landing (VTOL) airplane in hovering and transition flight. The model was powered with compressed air jets one in each wing-tip nacelle and two in the fuselage. In hovering flight the model was controlled by jet-reaction controls which consisted of pitch and yaw jets at the rear of the fuselage and a differential change in the thrust of the wing-tip jets for roll control. In forward flight the model was controlled by flap-type ailerons and all-movable horizontal and vertical stabilizers.

In hovering flight the model could be flown smoothly and easily, but the controls were considered too weak for rapid maneuvering or hovering in gusty air. Take-offs and landings in still air could be made smoothly with no noticeable ground effect on the behavior of the model. Transitions from hovering to normal forward flight could be made smoothly and easily. In a condition representing the proposed gliding landing approach of the airplane with the wing-tip nacelles at 90° incidence, the stability and control of the model was satisfactory at the lower angles of attack, but an uncontrollable directional divergence was encountered at angles of attack above about 19°. In normal forward flight the model could be flown smoothly and steadily at angles of attack of 12° to 13°. As the angle of attack was increased above 13° the aileron effectiveness and directional stability became undesirably low until at an angle of attack above 16° the model experienced an uncontrollable directional divergence. The use of a wing leading-edge flap or vertical tails on the order of 50 percent larger than the original tails increased the angle of attack at which the directional divergence occurred to about 20°.

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INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation has been made to determine the low-speed dynamic stability and control characteristics of a 1/8-scale flying model of the Bell D-188A jet vertical-take-off-and-landing (VTOL) airplane in hovering and transition flight. This airplane has a relatively small unswept wing with large rotatable engine nacelles on the wing tips. It is powered with eight turbojet engines, two in each wing-tip nacelle and four in the fuselage, with sufficient thrust for vertical take-off and landing. Take-offs and landings with the airplane in a horizontal attitude are made by tilting the wing-tip engines to a vertical attitude, turning on the lifting engines in the forward part of the fuselage, and deflecting the thrust of the two engines in the rear of the fuselage downward. In forward flight the wing-tip engines are horizontal, the two lifting engines in the forward part of the fuselage are turned off, and the thrust of the engines in the rear of the fuselage is directed to the rear. Control for hovering and low-speed flight is provided by jet-reaction controls located near the airplane's extremities. Aerodynamic controls consisting of ailerons and all-movable vertical- and horizontal-tail surfaces are provided for control in normal forward flight.

The results of force tests made to determine the low-speed power-off static stability and control characteristics of the 1/8-scale flying model are presented in reference 1.

The model flight investigation consisted of take-offs and landings, hovering flight, constant-altitude transitions between hovering and unstalled forward flight, and normal forward flight at angles of attack above 10°. The results of these tests are presented in this paper.

SYMBOLS

The longitudinal forces and moments are referred to the stability axes and the lateral forces and moments are referred to the body axes. These axes are shown in figure 1 which shows the positive direction of forces, moments, and angles. The symbols used in the paper are defined as follows:

S wing area, sq ft

b wing span, ft

V airspeed, ft/sec

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ρ	air density, slugs/cu ft
q	dynamic pressure, $\frac{\rho V^2}{2}$, lb/sq ft
c	chord, ft
α	angle of attack, deg
β	angle of sideslip, deg
F_Y	lateral force, lb
M_X	rolling moment, ft-lb
M_Y	pitching moment, ft-lb
M_Z	yawing moment, ft-lb
C_Y	lateral-force coefficient, F_Y/qS
C_l	rolling-moment coefficient, M_X/qSb
C_n	yawing-moment coefficient, M_Z/qSb
C_{Y_β}	variation of lateral-force coefficient with angle of sideslip, $\frac{\partial C_Y}{\partial \beta}$, per deg
C_{l_β}	variation of rolling-moment coefficient with angle of sideslip, $\frac{\partial C_l}{\partial \beta}$, per deg
C_{n_β}	variation of yawing-moment coefficient with angle of sideslip, $\frac{\partial C_n}{\partial \beta}$, per deg
δ_r	vertical-tail deflection, deg
δ_s	spoiler deflection, deg

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δ_D deflector deflection, deg

Δ prefix signifying increment of coefficient due to control deflection

APPARATUS AND TESTS

Model

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A multiple-exposure photograph of the model showing the wing-tip nacelles being tilted is presented in figure 2 and a sketch showing some of the more important dimensions is presented in figure 3. The wing-tip engine nacelles tilt through approximately 90° to a vertical attitude for vertical take-off and landing. In order to increase the inlet area to improve the engine thrust for the hovering and low-speed flight conditions, the inlets of the nacelles of the airplane slide forward as indicated by the inset sketch on figure 3 to open a large inlet around the nacelle. It is planned that the inlets be open at all airspeeds less than about 200 knots. Since the entire speed range represented in the model tests was within this range, the inlets were fixed in the extended position for all the flight test program. The model was powered by compressed air jets for all the flight tests. A jet was located in each wing-tip nacelle, one in the forward portion of the fuselage to represent the lifting engines and one near the rear to represent the rear engines with the thrust diverted downward. In hovering and transition flight the wing-tip jets gave a constant thrust approximately equal to the scaled-down nonafterburning thrust of the wing-tip engines on the airplane and the thrust of the fuselage jets was adjusted to maintain the desired altitude. Roll control in hovering flight was obtained by increasing the thrust on one wing-tip jet and decreasing the thrust on the other by means of a valve in the model. Pitch and yaw control for hovering flight was obtained by means of control jets located at the rear of the fuselage. Each of the jet-reaction controls was adjusted to give approximately the scaled-down moment produced by the jet-reaction controls of the airplane. The aerodynamic controls for forward flight consisted of ailerons and all-movable vertical- and horizontal-tail surfaces that could be used separately or together with the jet-reaction controls at the option of the pilots. All controls (aerodynamic and jet) were of the flicker type (full on or off) with integrating trimmers generally used in free-flight models. These trimmers trimmed the control a small amount in the direction the control was moved each time a control deflection was applied. With actuators of this type, a model becomes accurately trimmed after flying a short time in a given flight condition. The deflections applied by a flick of the controls were:

Horizontal tail . . . . $\pm10^{\circ}$
Vertical tail . . . . $\pm8^{\circ}$
Ailerons (each) . . . . $\pm20^{\circ}$

The thrust of the lifting and propulsion jets was adjusted by means of a valve in the air supply line with approximately 35 feet of flexible hose between the valve and the model.

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The mass characteristics of the model are given in table I. These values represent approximately the scaled-down values of the airplane in the landing condition (airplane with armament expended and 1,800 pounds of fuel). There was one difference between the model and the present configuration of the airplane which might have some significant effect on stability and control in the transition range. The model represented an early configuration of the airplane in which a part of the leading edge of the wing near the tip tilted with the nacelle. It is understood that this feature has been eliminated in later configurations of the airplane. The jet-reaction control forces were adjusted to produce the scaled-down control moments of the airplane. These values of the control forces were an up or down force of ±1 pound at the rear of the airplane for pitch control, a side force of ±1.2 pounds at the rear of the airplane for yaw control, and a variation of the thrust of each wing-tip nacelle of ±1 pound for roll control. These values were maintained throughout the tests except where otherwise specifically noted.

Test Equipment and Setup

Transition and normal forward-flight tests were conducted in the Langley full-scale tunnel; the take-off, landing, and hovering flight tests were conducted in a large building free from the effects of outside air gusts.

Figure 4 shows the test setup for the flight tests in the Langley full-scale tunnel. The sketch shows the pitch pilot, the safety-cable operator, and the power operator on a balcony at the side of the test section. The roll pilot was located in an enclosure in the lower rear part of the test section, and the yaw pilot was at the top rear of the test section. The pitch, roll, and yaw pilots were located at the best available vantage points for observing and controlling the particular phase of the motion with which each was concerned. Motion-picture records were obtained with fixed cameras mounted near the pitch and yaw pilots.

The air for the main propulsion jets and for the jet controls was supplied through flexible plastic hoses while the power for the electric trim motors and control solenoids was supplied through wires. These wires and tubes were suspended overhead and taped to a safety cable

(1/16-inch braided aircraft cable) from a point approximately 15 feet above the model down to the model. The safety cable, which was attached to the top of the wing over the center of gravity, was used to prevent crashes in the event of a power or control failure, or in the event that the pilots lost control of the model. During the flight the cable was kept slack so that it would not appreciably influence the motions of the model.

The test technique is best explained by describing a typical flight. The model hung from the safety cable and the power was increased until the model was in steady hovering flight. At this point the tunnel drive motors were turned on and the airspeed began to increase. As the airspeed increased, the controls and power were operated and the wing-tip engine nacelles were tilted progressively into the wing so that the model maintained its fore-and-aft position in the test section until a particular phase of the stability and control characteristics was to be studied. Then the pilots performed the maneuvers required for the particular tests and observed the stability and control characteristics. The flight was terminated by gradually taking up the slack in the safety cable while reducing the power to the model.

The test technique used for the forward-flight tests was similar to the technique used for the transition-flight tests except for the start. For the forward-flight tests the model was towed with the safety cable as the airspeed of the tunnel was increased to the speed at which the model was to be tested. At this point the controls and power were operated so that the model became airborne. From this point on the technique was the same as that for the transition-flight tests.

A similar testing technique was used for the take-off, landing, and hovering flight tests except that these tests were conducted indoors in a large open building which kept the model free from the random effects of outside air gusts.

Tests

The investigation consisted mostly of flight tests to study the stability and control characteristics of the model. The stability and controllability were determined in various tests either qualitatively from pilots' observations or quantitatively from motion-picture records of the flights.

Flight tests were made in the test section of the Langley full-scale tunnel to determine the overall stability and control characteristics of the model in transition flight from hovering to forward flight. These flights were slow constant-altitude transitions covering a speed range from about 0 to 57 knots which correspond to full-scale airspeeds of

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0 to 161 knots. Since small adjustments or corrections in the tunnel airspeed could not be made readily, the pitch pilot and the power operator had to make adjustments continually to hold the model in the center of the test section. Flights were also made in which the airspeed was held constant at intermediate speeds so that the stability and control characteristics at a particular speed could be studied. The transition tests also included flights to represent the proposed landing-approach condition for the airplane in which the nacelles are at approximately 90° incidence and all the engines were at essentially idling power.

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Flight tests were also made in the test section of the Langley full-scale tunnel to determine the overall stability and control characteristics of the model in the normal low-speed forward-flight range. The tests covered an angle-of-attack range of about 10° to 20° for a speed range of 54.5 to 48 knots which represents speeds from 154 to 136 knots for the full-scale airplane. The tests included flight tests with the model in the original configuration, with several vertical-tail modifications, and with leading-edge flaps on the wings. A few force tests were also made for the normal forward-flight condition to supplement the results of the main force-test investigation of reference 1. The control effectiveness of the original vertical tail was measured for a deflection of 8° which is the maximum deflection planned for the full-scale airplane. The effectiveness of a spoiler-slot-deflector aileron suggested by the manufacturer, and shown in figure 5, was also measured.

Hovering-flight tests were made with the model hovering at heights of 5 to 15 feet above the ground to determine the basic stability and controllability of the model. These tests also included take-offs from and landings on the ground to determine the effect of the proximity of the ground on the flight behavior of the model. A few force tests were also made to determine the variation of pitching moment and lift with height of the model above the ground. These tests were made with the apparatus used in a similar investigation reported in reference 2.

RESULTS AND DISCUSSION

A motion-picture film supplement illustrating the flight-test results has been prepared and is available on loan. A request-card form and a description of the film will be found at the back of this paper, on the page immediately preceding the abstract and index pages.

Hovering Flight

The model could be flown smoothly in hovering flight in still air and could be moved readily from one position to another. The pitch and

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roll jet-reaction controls were not as strong as might be desired, and it was sometimes difficult for the pilots to settle the model down and restore it to a steady-flight condition after it had been allowed to move about quickly or after it had been disturbed by a violent motion of the flight cable or by turbulence in the air in the test area induced by the compressed air jets in the model. With the thrust of the jet-reaction controls increased to give approximately 1.6 times the scaled-down control moment, the model could be maneuvered fairly easily but the flicker-type control used in the model gave too much control for smooth hovering flight. The results of these tests indicate that the pilot would have sufficient jet-reaction control for hovering the full-scale airplane in still air but a stronger control would be desirable to overcome disturbances such as might be experienced in gusty air.

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Take-Offs and Landings

Take-offs and landings could be made very smoothly in still air but the jet-reaction controls were considered barely adequate for these tests as was the case for hovering flight. It would probably be very desirable to provide a more powerful control for take-offs and landings in gusty air. There was no noticeable change in pitch trim as the model approached the ground although the results of some force tests which are presented in figure 6 indicate a nose-up change in pitch trim when the model is near the ground. In the flight tests the model probably passed through this region too quickly for the pilot to notice any change in trim since the moment involved is not large enough to provide a very high pitching acceleration, even though it appears large in proportion to the pitch-control moment of approximately ±3 pound feet. The data of figure 6 are presented as a band since there was considerable scatter of the test points, probably because of differences in the reaction forces and moments of the air supply hose as the model was moved from one position to another. The band shown covers the entire range of the scatter for the 25 points covered in the tests. The lift and drag were also measured during these ground-effect force tests, and it was found that there was no measurable variation of either lift or drag with height for the heights tested.

Transition Flight

Transitions from hovering to normal forward flight could be made smoothly and easily in the Langley full-scale tunnel and the model seemed to have stability of angle of attack over most of the speed range. At times, the model would fly "hands off" in pitch for reasonably long periods of time when it was trimmed correctly and the airspeed was not being changed. These flights in the full-scale tunnel represented slow, constant-altitude transitions at an angle of attack of about 0°.

The lateral stability and control characteristics of the model were also generally satisfactory in these transitions. During the transition the roll pilot found it desirable to switch out the roll jet-reaction control and fly with only the ailerons for control at nacelle incidence angles less than about 60°. The point at which this switching out of the jet roll control will be desirable for the airplane will not be the same as that for the model because the thrust axes of the roll jets on the airplane do not rotate exactly with the wing-tip nacelles as was the case with the model. On the full-scale airplane roll control is obtained by bleeding the compressor of the engines in one wing-tip nacelle and exhausting the air upward through a nozzle fixed in the wing. The roll control force therefore results from two elements - a 141-pound downward force from the nozzle fixed in the wing, and a 449-pound deterioration of engine thrust which tilts with the nacelle.

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Landing-Approach Condition

The proposed technique for making a landing approach with the airplane consists of a glide at an angle of attack of 10° or less with all engines idling and their thrust directed downward. Since the glide could not be performed in the wind tunnel, the model was powered for these tests by compressed air jets at the rear of the fuselage so that it could fly level. This difference in flight-path angle would not be expected to have any large effect on the stability and control characteristics.

In these tests simulating the proposed landing-approach condition (nacelles at 90° incidence with no power), the stability and control of the model was satisfactory at lower angles of attack. As the angle of attack increased, the aileron effectiveness and directional stability dropped off until at angles of attack above about 19° the model experienced a directional divergence in which it would diverge either to the right or left against full corrective rudder and aileron control.

Normal Forward Flight

In normal forward flight (nacelles at 0° incidence with power on), the model could be flown smoothly and steadily at angles of attack of 12° to 13°. No flights were made at lower angles of attack because the roughness of the tunnel air flow at high speeds and the flicker-type control used on the model (full on or full off) made the model very erratic and jumpy. As the angle of attack was increased above 13°, the aileron effectiveness and directional stability became undesirably low until at angles of attack above 16° the model experienced a directional divergence in which it would diverge either to the right or left against full corrective rudder and aileron control.

These results may not appear to be in quantitative agreement with the results of the force tests of reference 1 but actually are in agreement if the results of the force tests are analyzed in terms of the dynamic motions of the model in the light of past experience. For example, the force tests show very little reduction in the aileron rolling moments between 12° and 16° angle of attack but show a large increase in aileron adverse yawing moment. The force tests also show that the static directional stability drops off from a value of about 0.001 at an angle of attack of 12° to about -0.003 at an angle of attack of 16°, whereas the effective dihedral parameter C_{l_β} changes from -0.0025 to about -0.0012. The results of the rudder-effectiveness force tests presented in figure 7 of the present paper show a marked reduction in rudder effectiveness at angles of attack above 12°. When all five of these factors are taken into account it seems that, when the ailerons were deflected at angles of attack above about 13°, they produced a sizable direct rolling moment, but the accompanying adverse yawing moment was greater than the yawing moment available from the rudder so that the model would develop a considerable amount of sideslip because of the low or negative directional stability and the positive effective dihedral (that is, negative C_{l_β}) would then produce a rolling moment opposing that of the ailerons. The aileron effectiveness would therefore appear to be much lower than would be indicated by the direct aileron rolling moments. The fact that the directional divergence did not occur at an angle of attack of 13° when C_{n_β} became zero but was delayed at an angle of attack of 16° when C_{n_β} had become -0.003 is consistent with past experience. It has generally been found that, when a configuration has positive effective dihedral, a considerable amount of static directional instability (negative C_{n_β}) is required to cause a directional divergence. An outstanding example of this result is obtained by comparison of the stability of the two superficially similar delta-wing models previously tested in the Langley free-flight tunnel (XP-92 and YF-102). The XP-92 model, which had positive effective dihedral, did not experience a directional divergence at the stall in spite of the fact that it had a large amount of negative directional stability, whereas the YF-102 model experienced a directional divergence at exactly the angle of attack at which C_{n_β} became zero. This characteristic is also supported by the results obtained with a number of other configurations, although in less spectacular fashion because of the superficial similarity of these two models.

Several tests were made to determine means of eliminating or delaying the directional divergence. The devices covered in these tests were (1) use of the jet-reaction controls in the normal forward-flight

configuration, (2) use of wing leading-edge flaps, and (3) the use of various modified vertical tails.

In flights made with the jet-reaction yaw control operating in addition to the rudder and ailerons, the model was flown successfully at angles of attack up to 23° in the original configuration. Although the proposed control system for the airplane in normal forward flight does not call for jet-reaction controls such a control would be one means of modifying the airplane to permit flights at the higher angles of attack before diverging in yaw.

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The addition of a full-span leading-edge flap to the wing as shown in figure 8 made it possible to fly the model in the original configuration with the aerodynamic controls at angles of attack up to 20° before the directional divergence occurred. The leading-edge flap improved the flow over the wing and ailerons and thereby gave better control at the higher angles of attack. The results of some tuft tests to study the flow over the wing are presented in figure 9 and serve to illustrate the improvement in the flow over the wing caused by the leading-edge flap. The results of the force tests of reference 1 show that at an angle of attack of 16°, the highest covered in the tests, the leading-edge flap caused a 30-percent increase in the aileron rolling moment and a 20-percent reduction in the adverse aileron yawing moment. The effect of the leading-edge flap on the static directional stability was not determined in the force tests.

In order to determine the effect of an enlarged upper vertical tail on the forward-flight behavior of the model, flight tests were made with an upper vertical tail 52 percent larger than the original vertical tail. With this enlarged vertical tail which was tail V_{u1} of reference 1 and is shown in figure 10 the model could be flown up to an angle of attack of about 19° before the directional divergence occurred. In an effort to improve the directional stability further, the model was fitted with the leading-edge flap in addition to the enlarged upper vertical tail. In this condition the model could be flown up to an angle of attack of about 21° before the directional divergence occurred.

Flight tests were also made with a modified vertical-tail arrangement suggested by the manufacturer which is shown in figure 11 and in reference 1. This modification consisted of a 66-percent larger upper vertical tail and three relocated ventral tails. With this vertical-tail modification the model could be flown up to an angle of attack of about 20° before the directional divergence occurred. The use of the leading-edge flap in conjunction with the revised vertical tails suggested by the manufacturer increased the angle of attack at which the directional divergence occurred to about 22°.

The results of the force tests to determine the effectiveness of a spoiler-slot-deflector aileron suggested by the manufacturer are presented in figure 12. The data show that for the range of deflections tested these ailerons produce less than one-half the rolling moment of the original ailerons at zero angle of attack and that, at angles of attack of 12° to 16° and at maximum deflection, the effectiveness had dropped off to about one-half the value at zero angle of attack. The adverse yawing moments of the spoiler-slot-deflector ailerons, however, were much less than those of the original ailerons.

SUMMARY OF RESULTS

The results of a flight investigation of the stability and control characteristics of a 1/8-scale flying model of the Bell D-188A jet VTOL airplane in hovering and transition flight can be summarized as follows:

1. In hovering flight in still air the model could be flown smoothly and moved easily from one position to another. The jet-reaction controls were not as strong as was desired for restoring the model to steady flight after it had been disturbed.

2. Take-offs and landings in still air could be made smoothly with no noticeable ground effect on the flight behavior of the model.

3. Transitions from hovering to normal forward flight could be made smoothly and easily.

4. In a condition representing the proposed gliding landing approach of the airplane with the wing-tip nacelles at 90° incidence the stability and control of the model was satisfactory at the lower angles of attack, but an uncontrollable directional divergence was encountered at angles of attack above about 19°.

5. In normal forward flight the model could be flown smoothly and steadily at angles of attack of 12° to 13° As the angle of attack was increased above 13°, the aileron effectiveness and directional stability became undesirably low until at angle of attack above 16° the model experienced an uncontrollable directional divergence.

6. The addition of a leading-edge flap to the wing made it possible to fly the model up to an angle of attack of 20° before the directional divergence occurred.

7. The use of vertical tails on the order of 50 percent larger than the original tails also delayed the directional divergence to an angle of attack of about 20°.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 20, 1959.

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REFERENCES

1. McKinney, Marion O., and Smith, Charles C., Jr.: Low-Speed Wind-Tunnel Tests of a 1/8-Scale Model of the Bell D-188A VTOL Airplane - TED No. AD 3147. NACA SL58H15, Bur. Aero., 1958.

2. Newsom, William A., Jr.: Effect of Ground Proximity on the Aerodynamic Characteristics of a Four-Engine Vertical-Take-Off-and-Landing Transport-Airplane Model With Tilting Wing and Propellers. NACA TN 4124, 1957.

TABLE I

MASS CHARACTERISTICS OF MODEL

	1/8-scale model	Full-scale airplane
Weight (landing condition), lb	29	14,848
Center-of-gravity location:		
Distance from leading edge of the mean aerodynamic chord, percent	31.30	31.30
Inertias:		
I_X, slug-ft^2	0.44	14,418
I_Y, slug-ft^2	1.78	58,327
I_Z, slug-ft^2	2.07	67,830

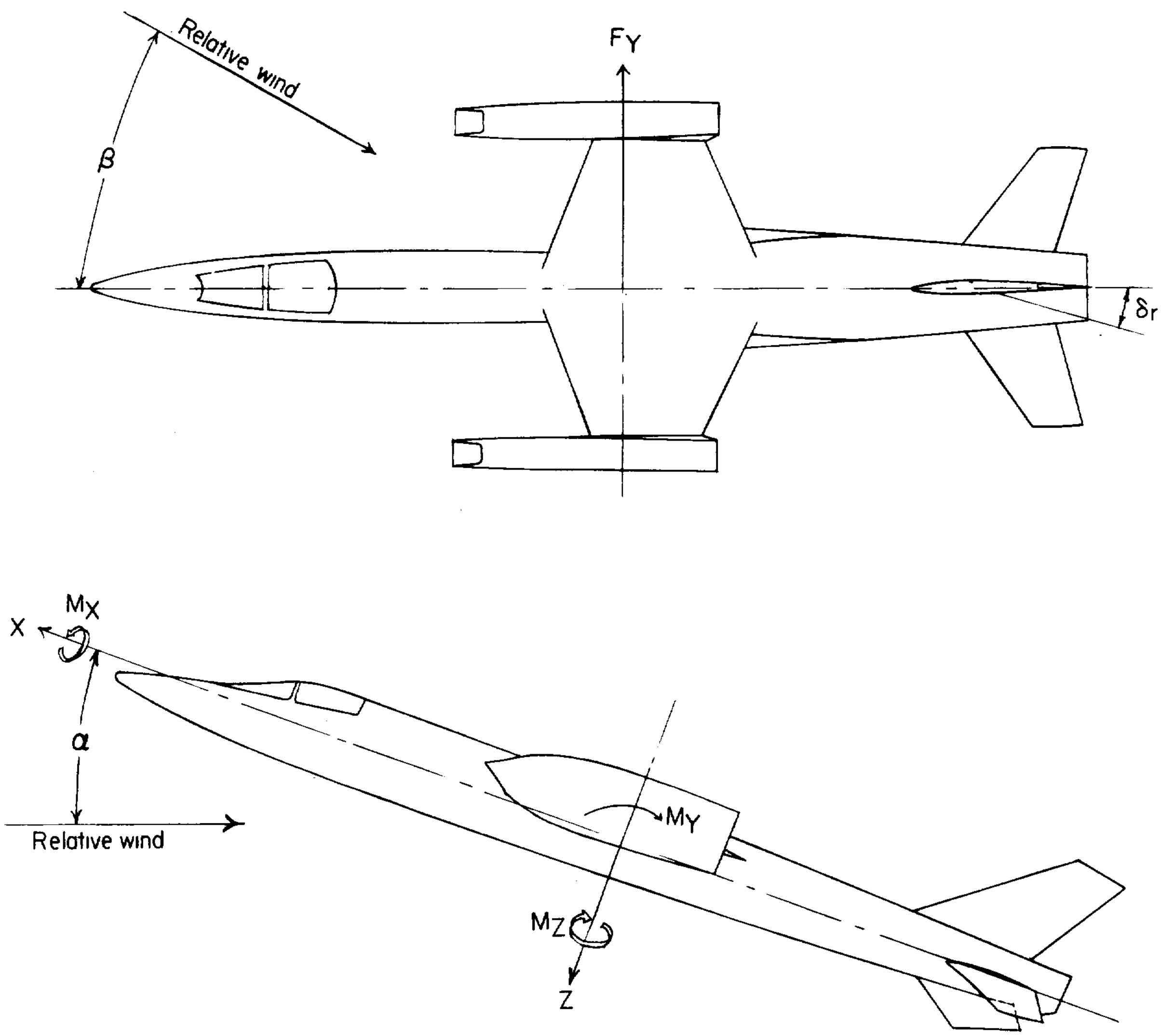

Figure 1.- Sketch of body system showing positive direction of forces, moments, and angles.

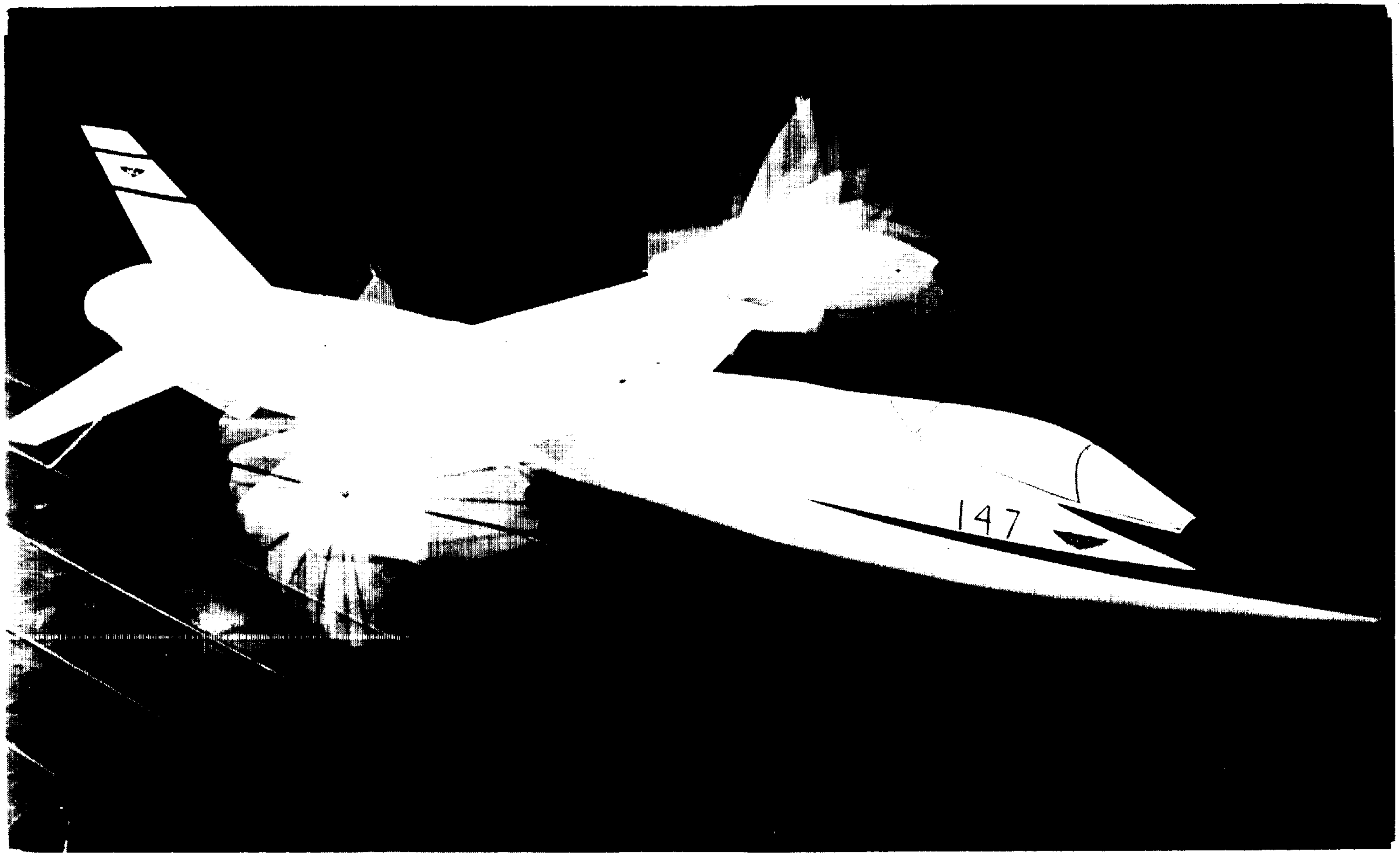

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Figure 2.- A multiple-exposure photograph of the 1/8-scale Bell D-188A jet VTOL model showing the wing-tip nacelles being tilted.

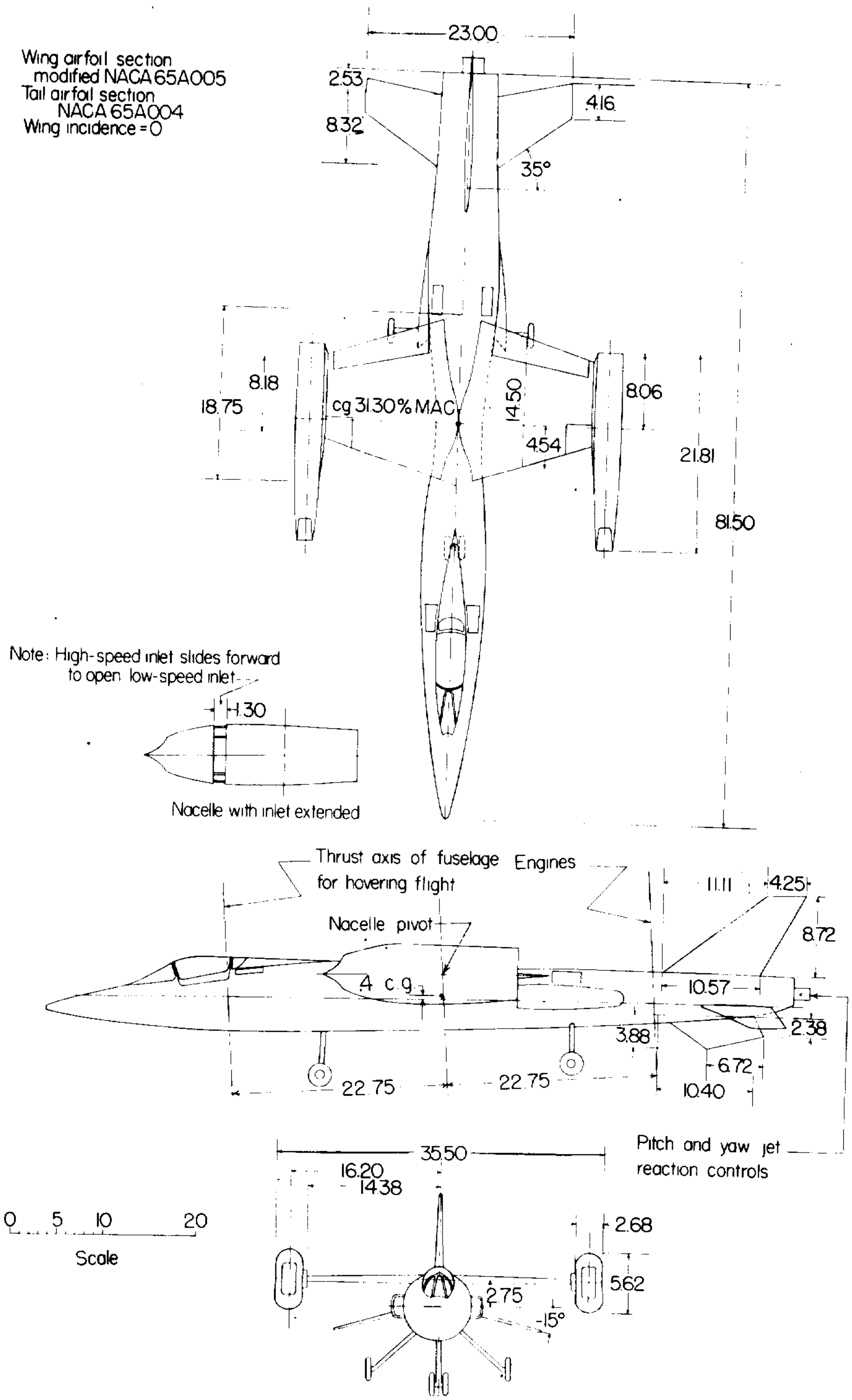

Figure 3.- Sketch of model in original configuration. All dimensions are in inches.

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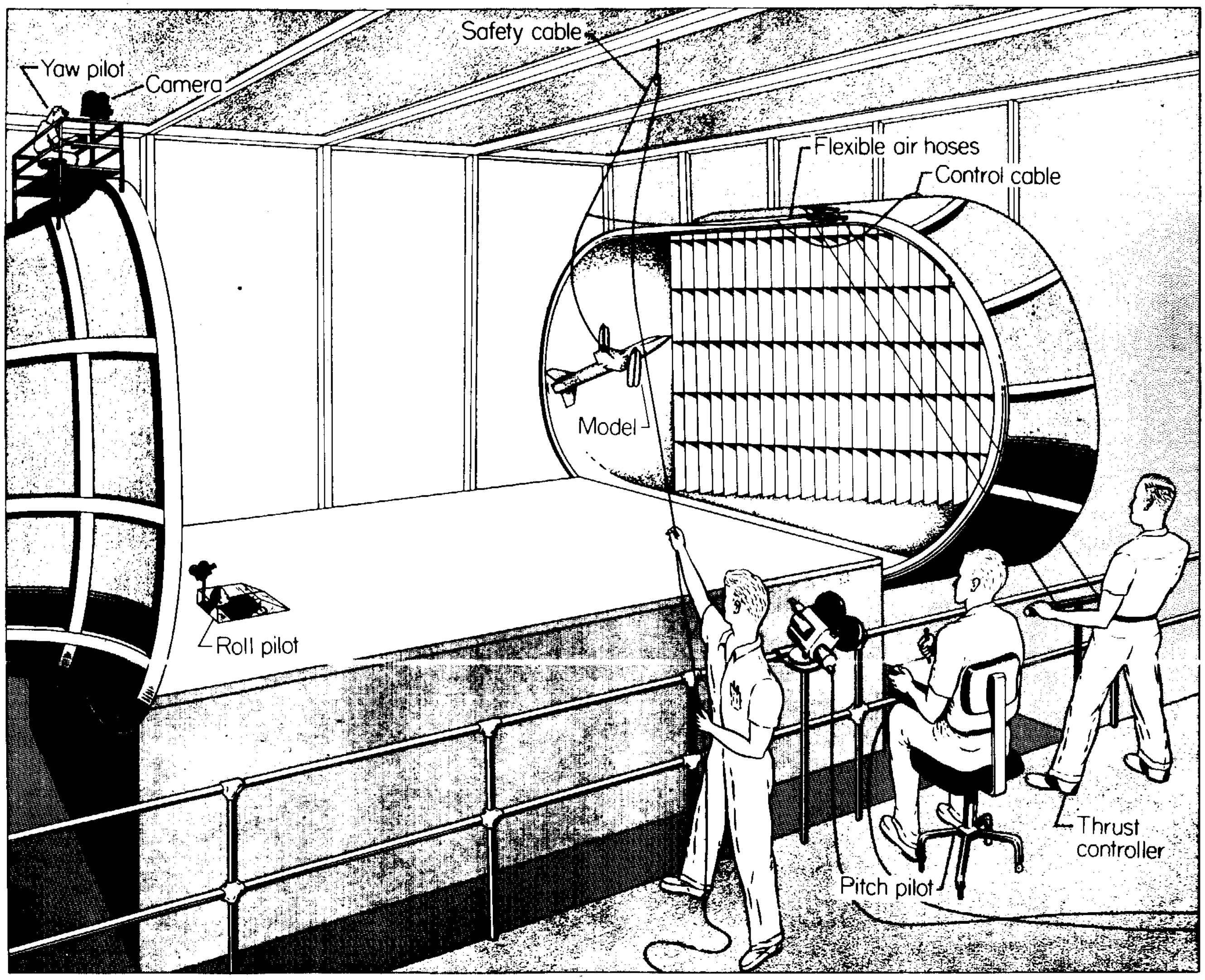

Figure 4.- Transition test setup in Langley full-scale tunnel.

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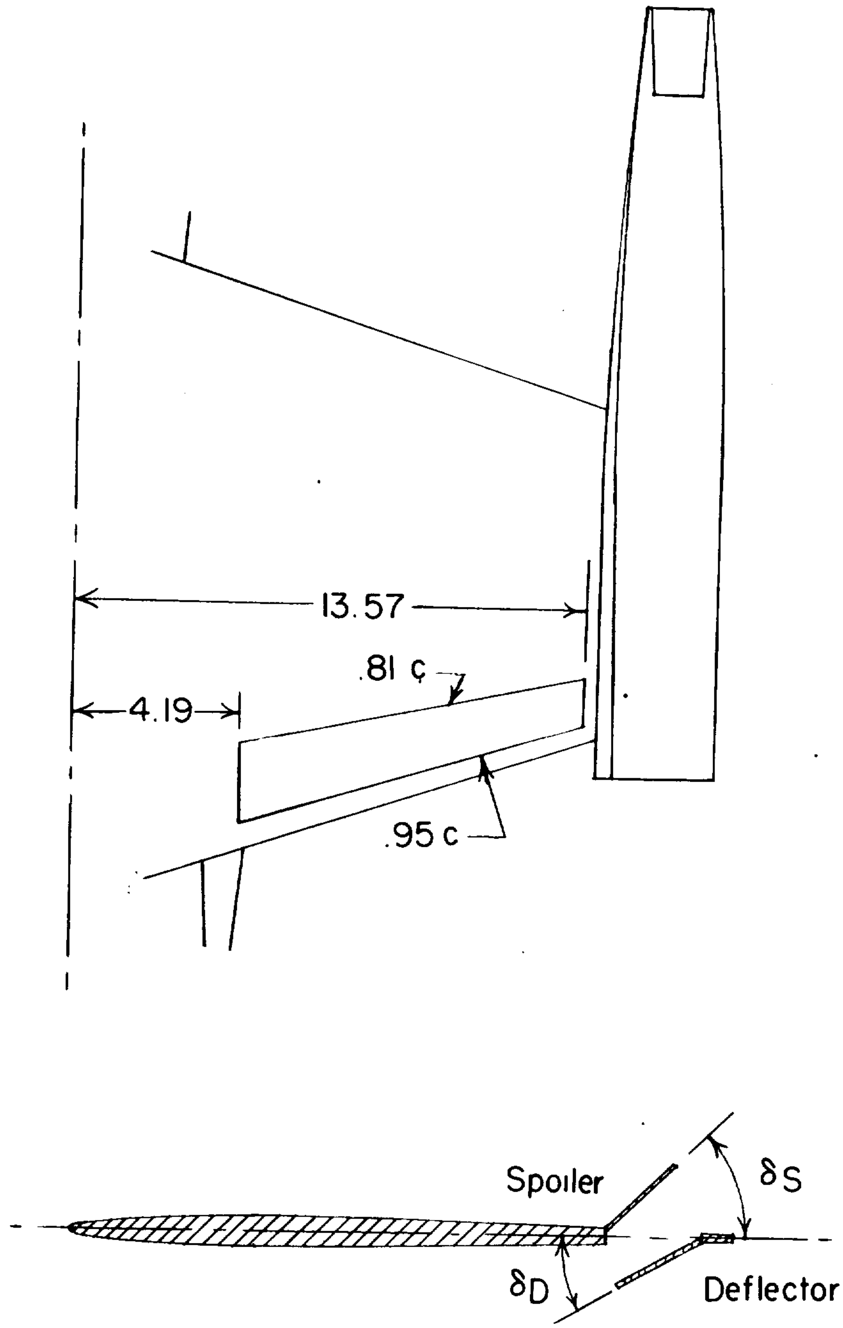

Typical section

Figure 5.- Spoiler-slot-deflector aileron.

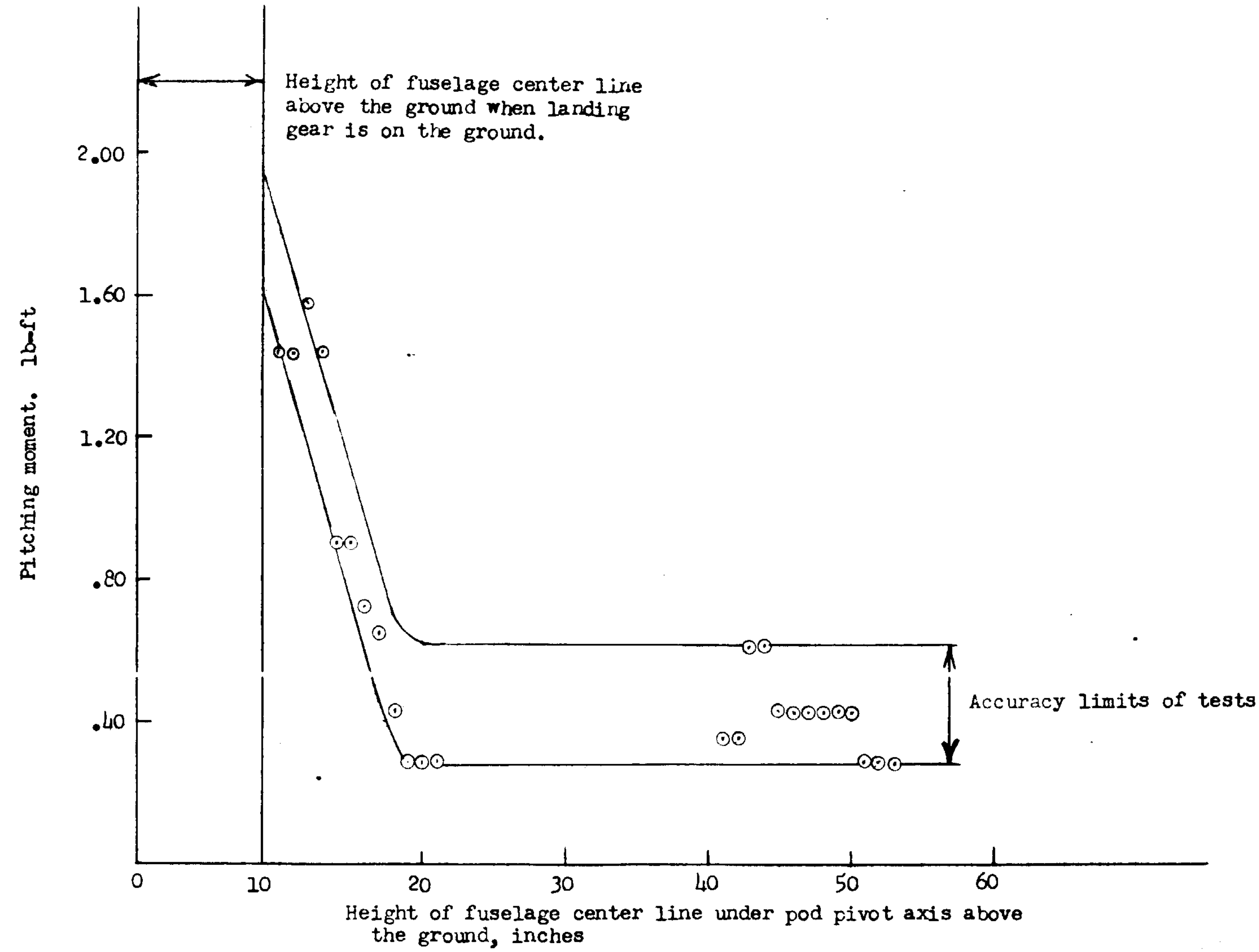

Figure 6.- Effect of ground proximity on the longitudinal trim of the Bell D-188A model.
Drag, 0; lift, 32 lbs.

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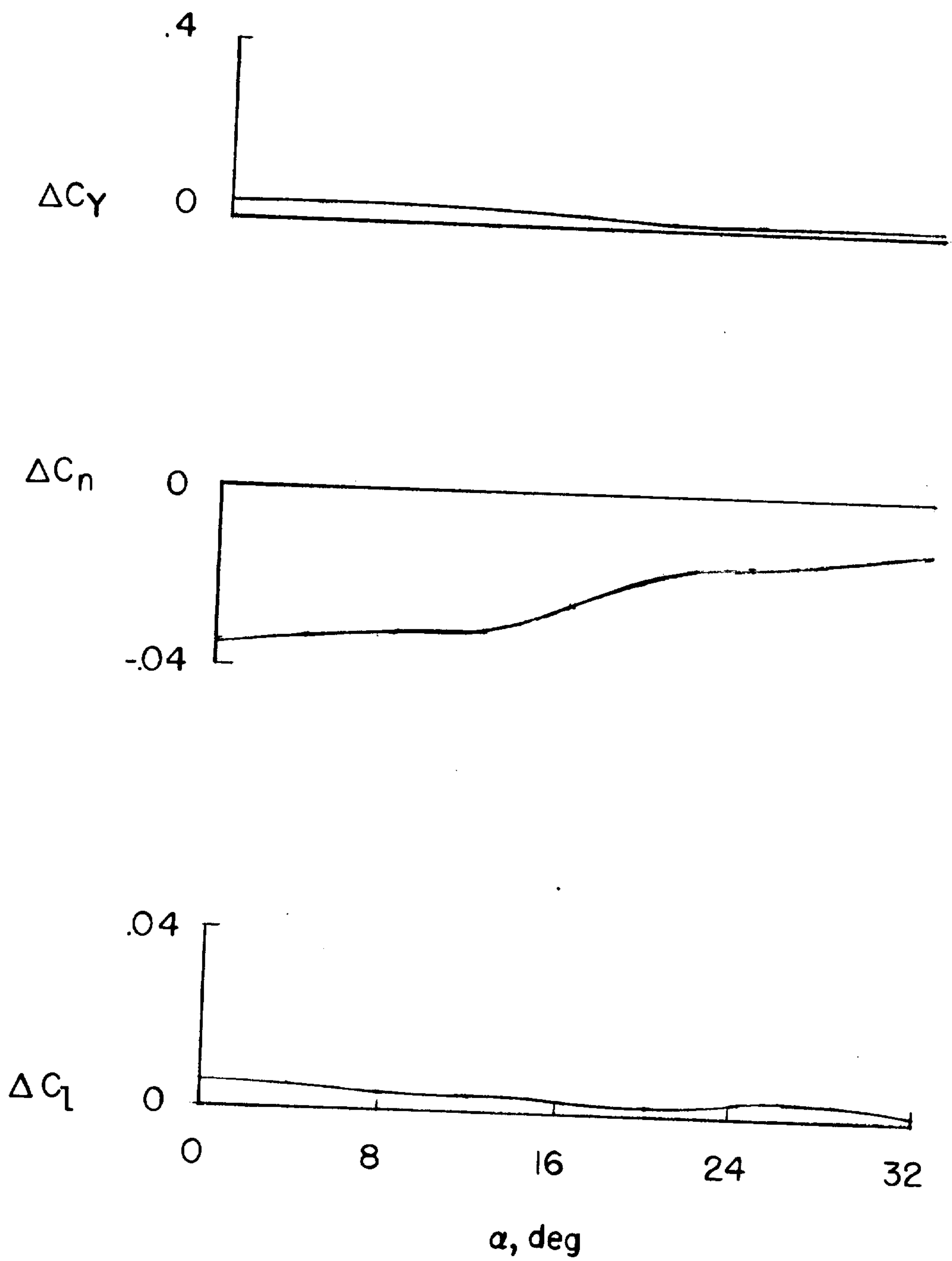

Figure 7.- Vertical-tail control effectiveness. $\delta_r = 8^{o}$.

[redacted]

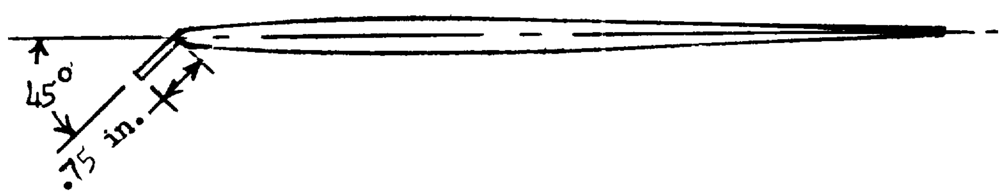

Figure 8.- Leading-edge flap.

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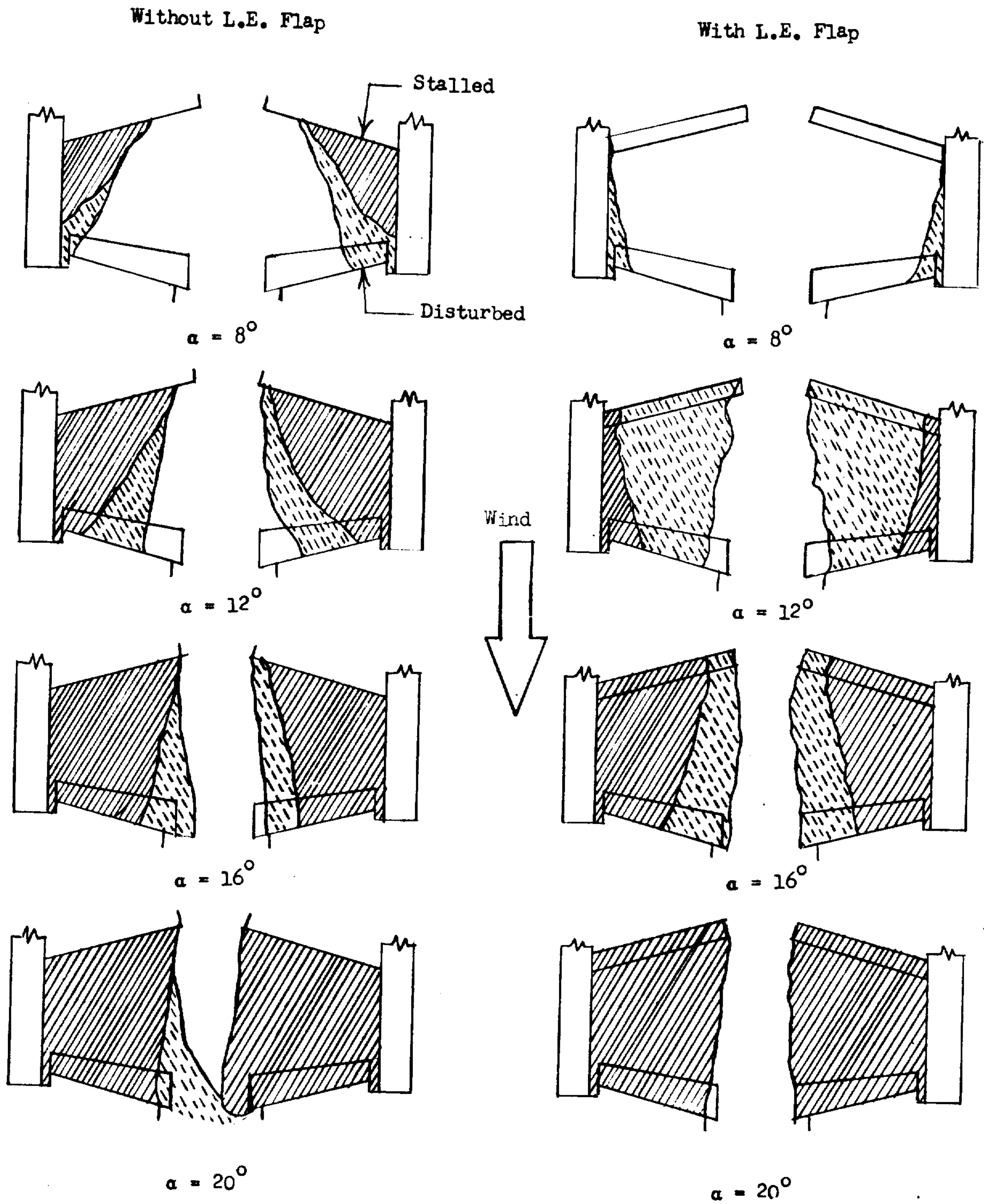
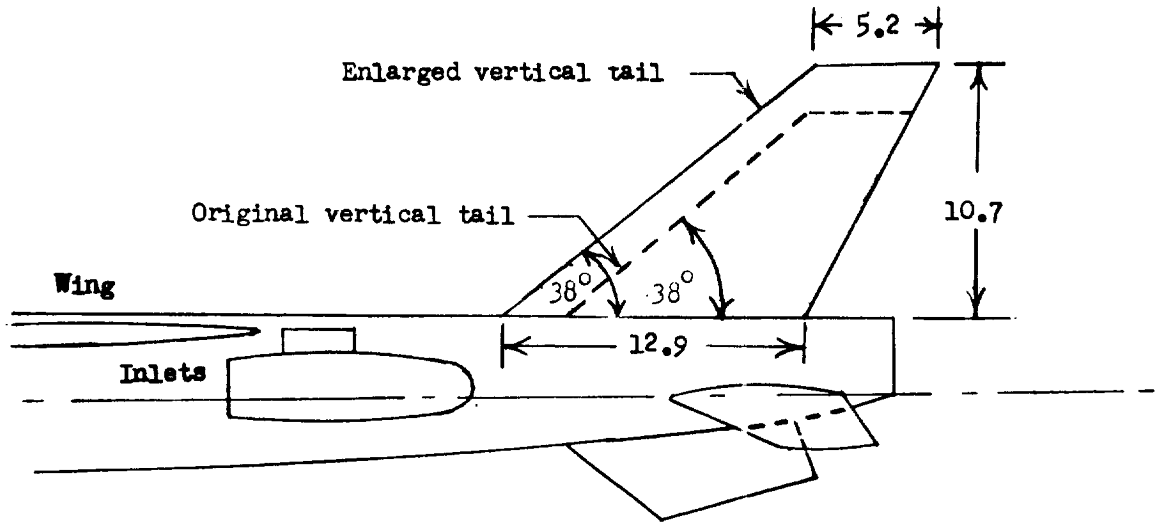


Figure 9.- Stall progression on upper surface of wing.

[redacted]



	Enlarged Vertical Tail	Original Vertical Tail
Aspect Ratio	1.18	1.18
Area	96.80 sq in	64.6 sq in

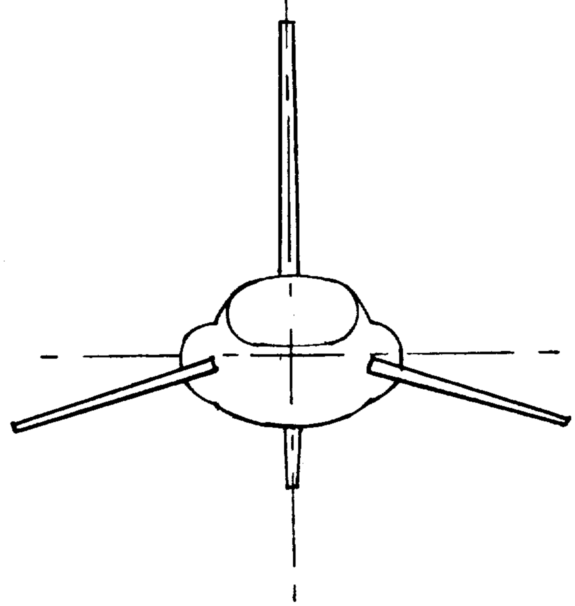


Figure 10.- Enlarged vertical tail. All dimensions are in inches unless otherwise noted.

[redacted]

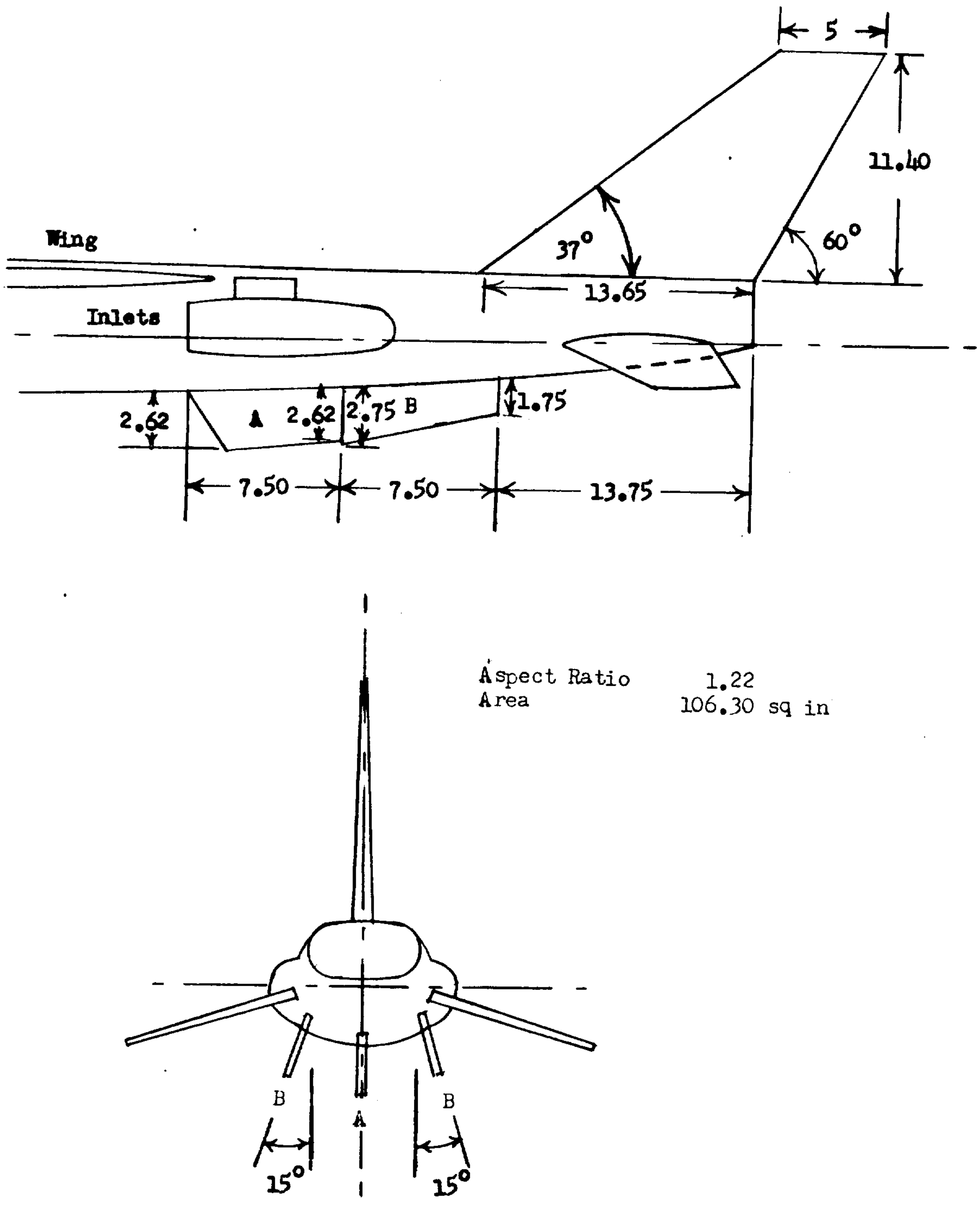


Figure 11.- Vertical-tail arrangement suggested by manufacturer. All dimensions are in inches.

[redacted]

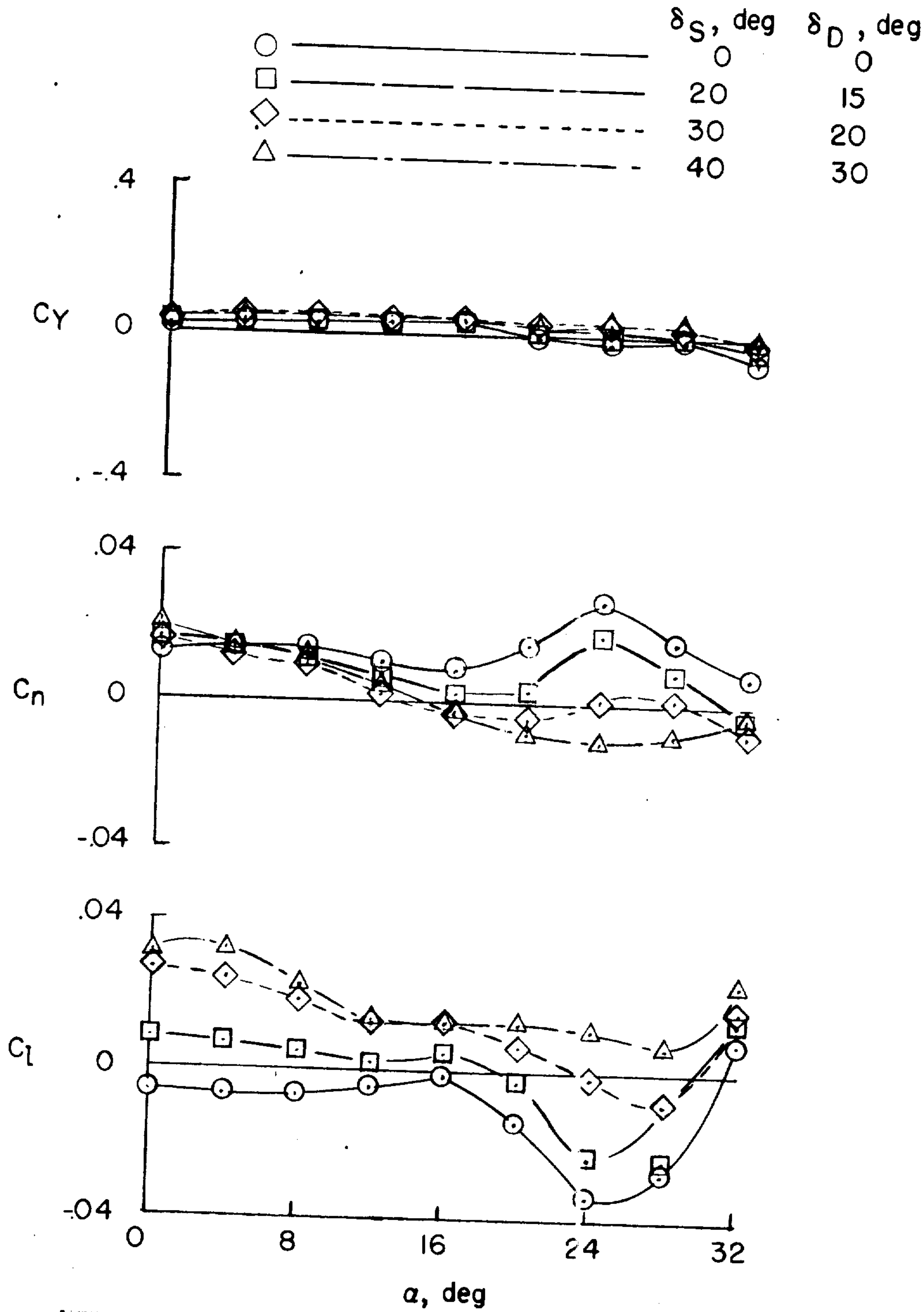


Figure 12.- Spoiler-slot-deflector effectiveness.

[redacted]